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HWR Cryomodule

Speaker: Peter N. Ostroumov

Contributors: Z.A. Conway, A. Barcikowski, S. Gerbick, C. Hopper,
M.P. Kelly, M. Kedzie, S. Kim and T. Reid

PIP-II Collaboration Meeting

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- Recent SRF infrastructure upgrade at ANL
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 - Magnet assemblies
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- FY17 and FY18 milestones
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FY15 Milestones

	Deliverables	Status
1	Complete all design work for the HWR cryomodule	Complete
2	Complete fabrication (including helium vessel) of all remaining 7 production cavities	Complete
3	Complete fabrication (including helium vessel) of all remaining 7 superconducting solenoids	Moved to Q2FY16
4	Perform cold/RF testing of the second prototype HWR together with SC solenoid	Complete
5	Complete assembly of cryostat vessel with thermal and magnetic shields installed	Complete
6	Complete fabrication of helium and vacuum manifolds	Complete
7	Complete fabrication of the strongback	Complete

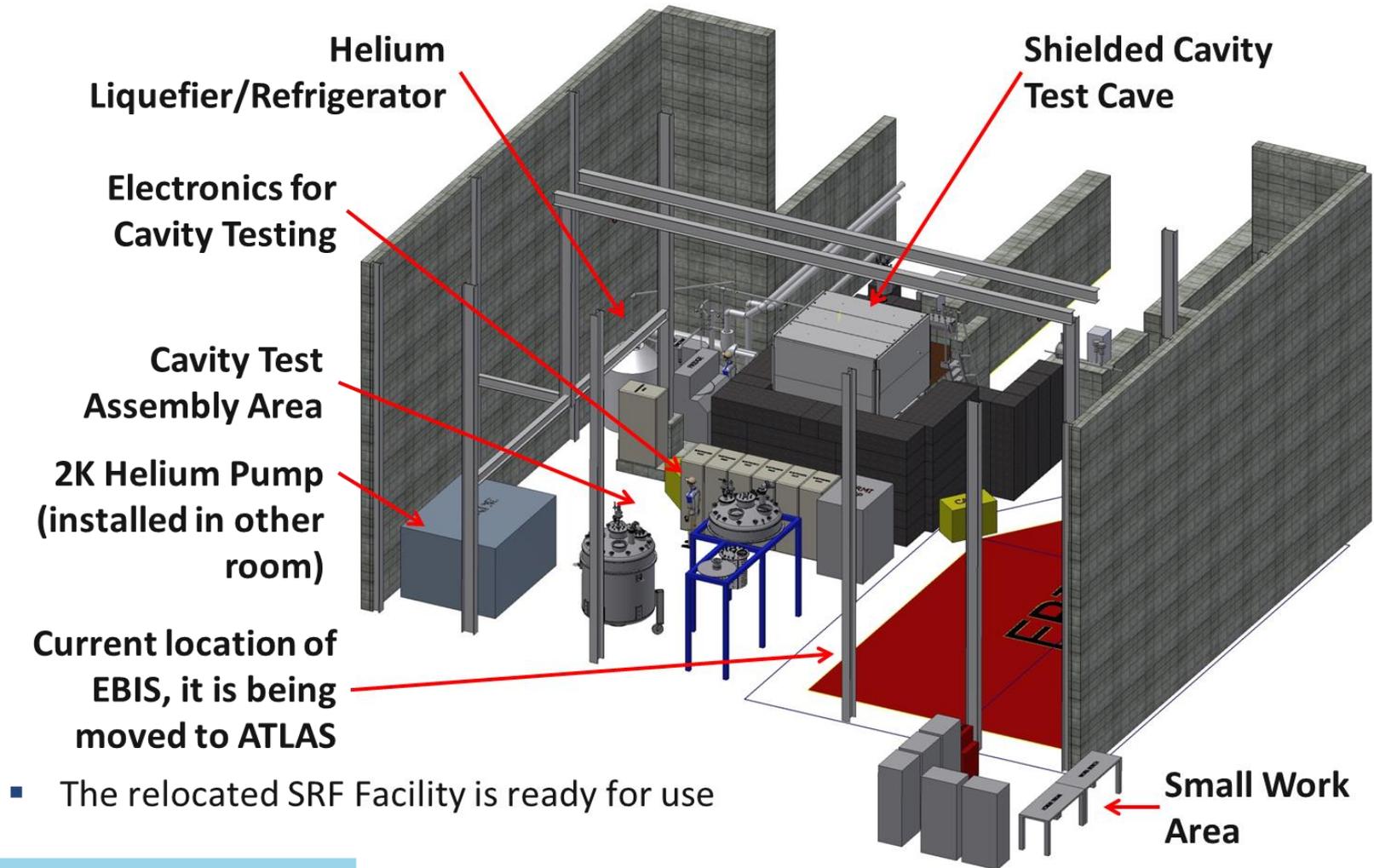
FY16 Milestones

- These milestones are consistent with the delivery of cryomodule to FNAL early FY18

	Deliverables	
1	Complete fabrication of magnet assemblies	Q2FY16
2	Complete fabrication of sub-systems (RF couplers, slow tuners and BPMs)	Q2FY16
3	Engineering cool down of the cryostat vessel to 80K	Q2FY16
4	Complete RF surface processing of 7 production cavities	Q3FY16
5	Testing of 7 production cavities individually in the test cryostat	Q4FY16

SRF Infrastructure Upgrade

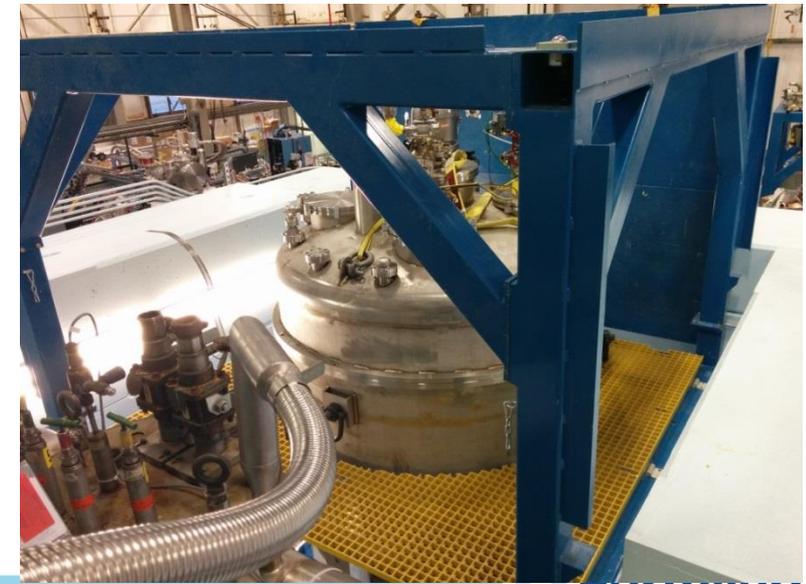
- SRF Cavity Test/Development Area in bldg. 203



- The relocated SRF Facility is ready for use

SRF Test Facility

- 100 W, 4K refrigerator
- ~30W, 2K with the helium pump
- All HWRs will be tested in the new facility



New Clean Room in Bldg. 366

- Footprint 16'x27'
- 35 ton Crane is available



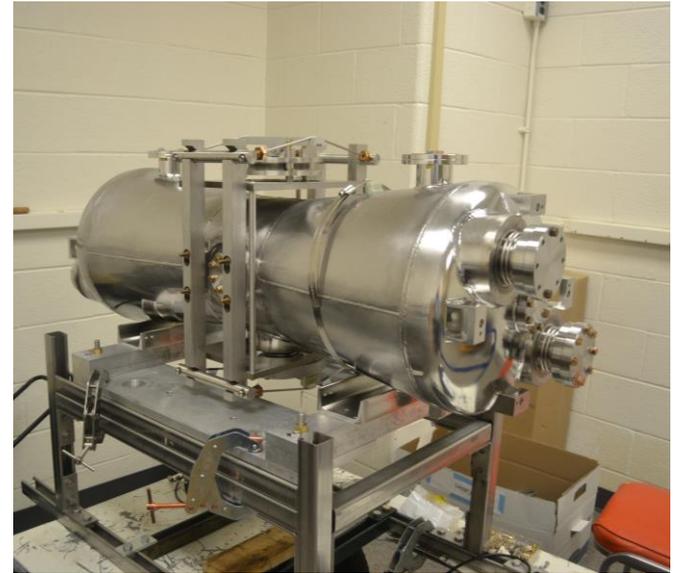
Status of 9 HWRs

- Q1, Q2, Q3, Q4 – subsequent quarters of FY16

HWR ID	0	1	2	3	4	5	6	7	8
Installation of helium jacket	Done								
Machining of fiducials	Done	Q1	Q1						
Bulk EP	Done	Done	Done	Done	Done	Done	Q1	Q1	Q1
625C baking	Done	Done	Done	Done	Done	Done	Q1	Q1	Q1
Frequency tuning	Done	Done	Done	Done	Done	Done	Q1	Q1	Q1
Final EP	Done	Done	Q1	Q2	Q2	Q3	Q3	Q3	Q4
Cleaning, HPR	Done	Done	Q1	Q2	Q2	Q3	Q3	Q3	Q4
Assembly for testing	Done	Done	Q1	Q2	Q2	Q3	Q3	Q3	Q4
Cold/RF testing	Done	Done	Q2	Q2	Q3	Q3	Q3	Q4	Q4

HWRs

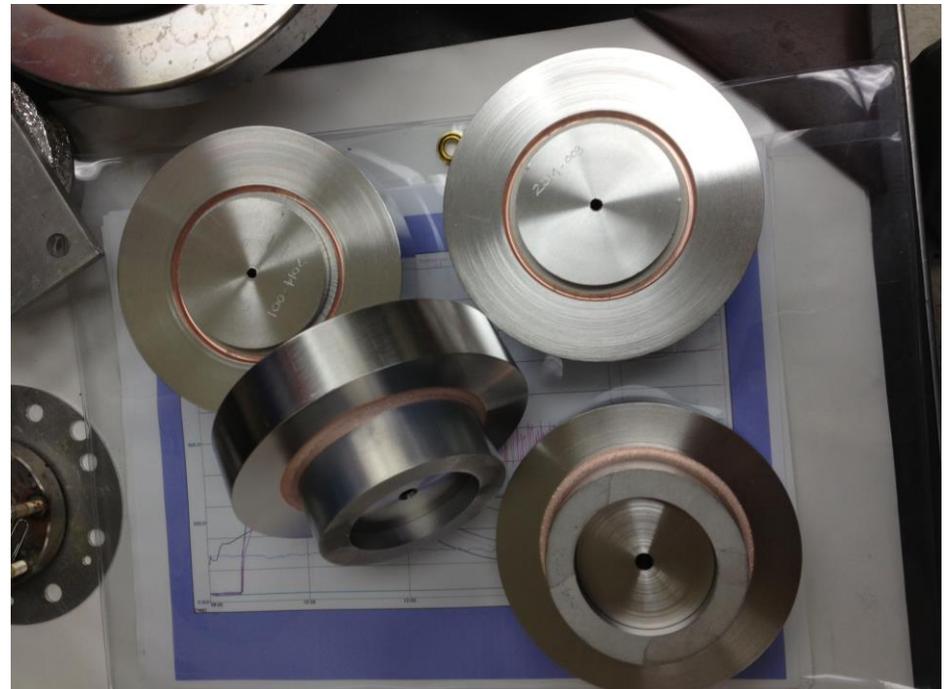
- Some of completed cavities
 - 2 HWRs at Meyer Tool
 - 1 is being installed for EP



Nb-SS Brazing Problems

- Leak developed after 625C bake
 - This issue was successfully resolved
- New design: 0.002" interference fit of Nb and SS parts
- 35 new coupling ports were built with 100% success

Faulted Nb-SS transition: copper layer is too thick



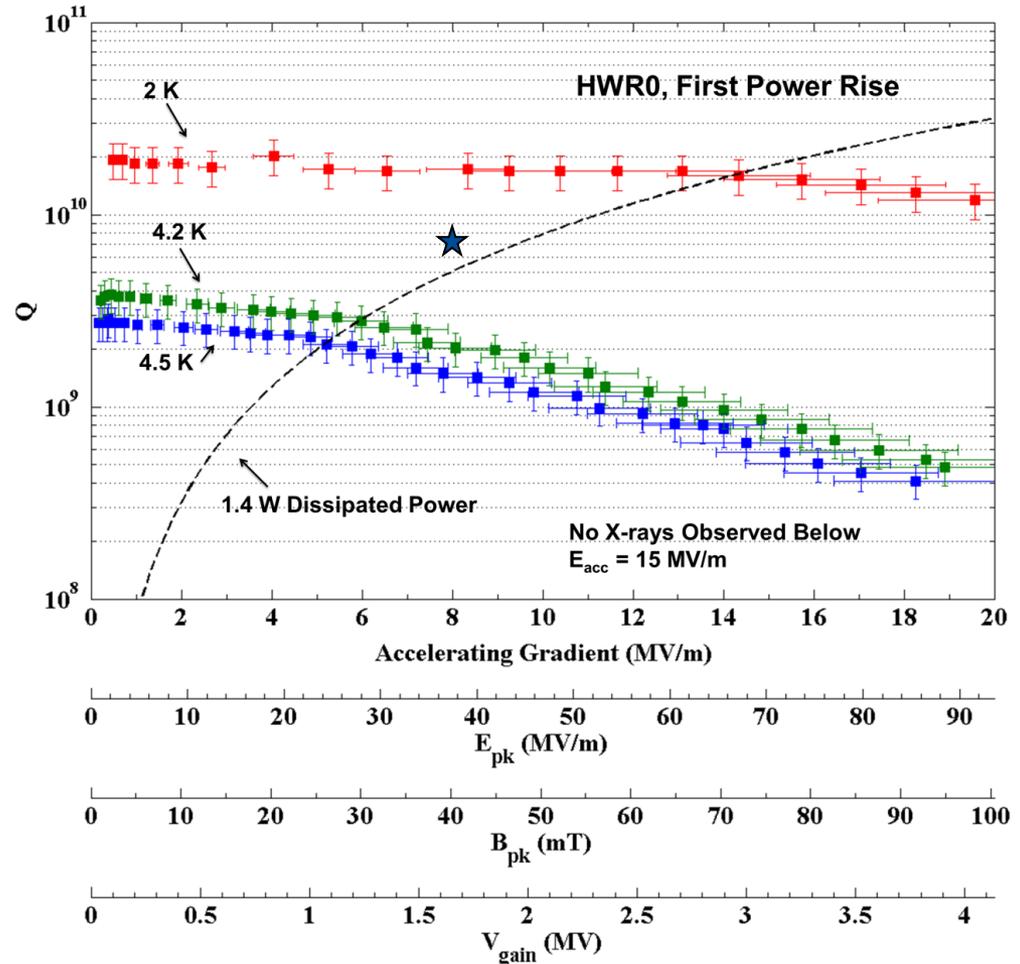
Beam Aperture Alignment

- Design beam aperture = $\phi 33.0$ mm.
- Wire-EDM bore of the beam aperture gives very accurate results:
 - Aperture diameter tolerance ± 0.04 mm.
 - Aperture pitch and yaw tolerance $< 0.1^\circ$.
- Wire-EDM is done prior to helium jacketing. The latter perturbs the pitch and yaw alignment by $< 0.1^\circ$.



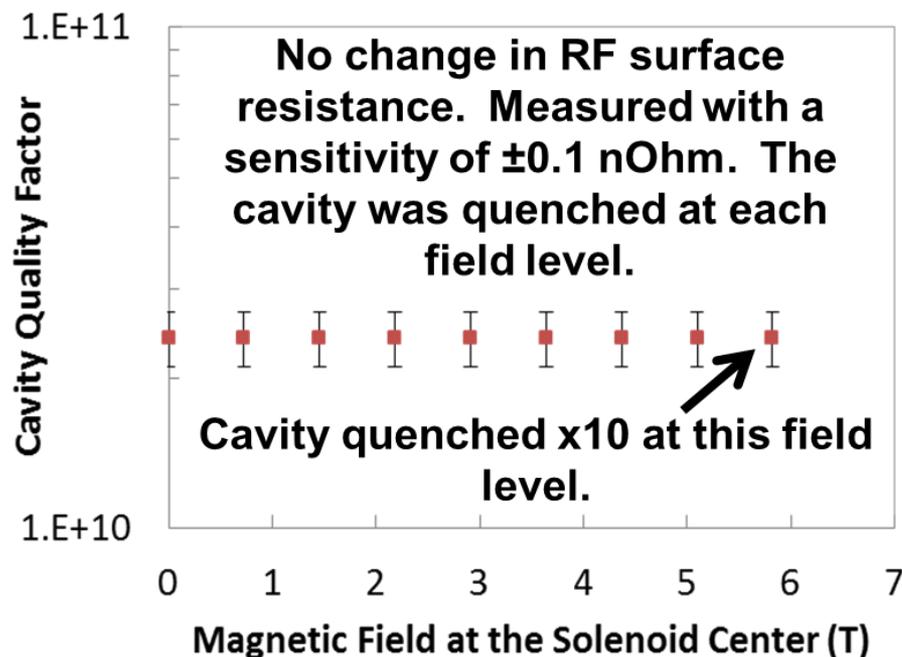
HWR Cold/RF Testing in FY14

- Performance sets a new world record in half-wave resonators
- The star is the design specification
- Testing was done with adjustable coupler at critical coupling
- Residual resistance is $< 2.6 \text{ n}\Omega$ up to $E_{\text{ACC}} = 14 \text{ MV/m}$
- Design field is 8 MV/m with $Q_0 = 7 \times 10^9$
 - Achieved $Q_0 > 1.7 \times 10^{10}$
- No X-rays observed below $E_{\text{ACC}} = 15 \text{ MV/m}$, or $E_{\text{PEAK}} = 70 \text{ MV/m}$

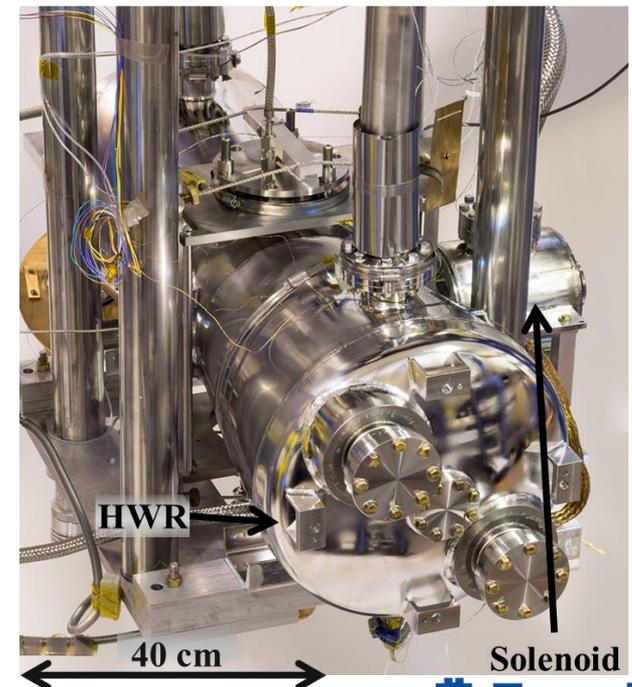


HWR Sensitivity to Solenoid Field

- To reduce the accelerator lattice length we have integrated X-Y-steering coils into the focusing solenoid package.
- Important design issue:
 - Minimize stray field @ the RF cavity to prevent performance degradation due to trapped magnetic flux.



HWR with Solenoid



Magnet Assemblies

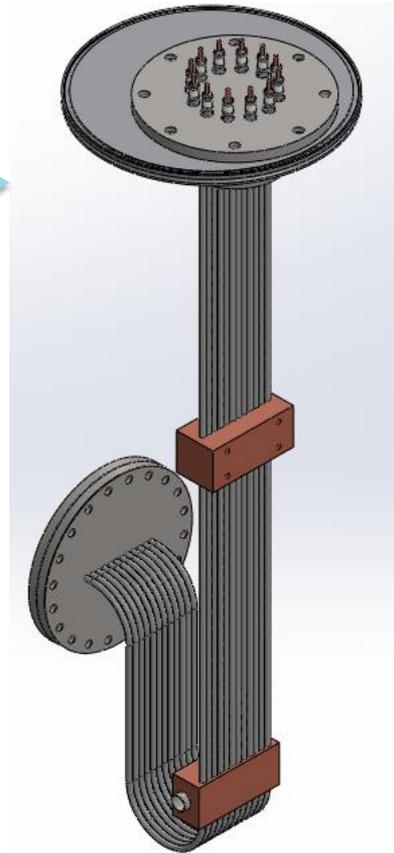
- Helium vessels on 4 magnet assemblies are completed
- We received 3 magnet assemblies from Cryomagnetics, the last one will be finished by the end of month

Magnet assembly.
Includes solenoid coil,
return coil and dipole
coils.



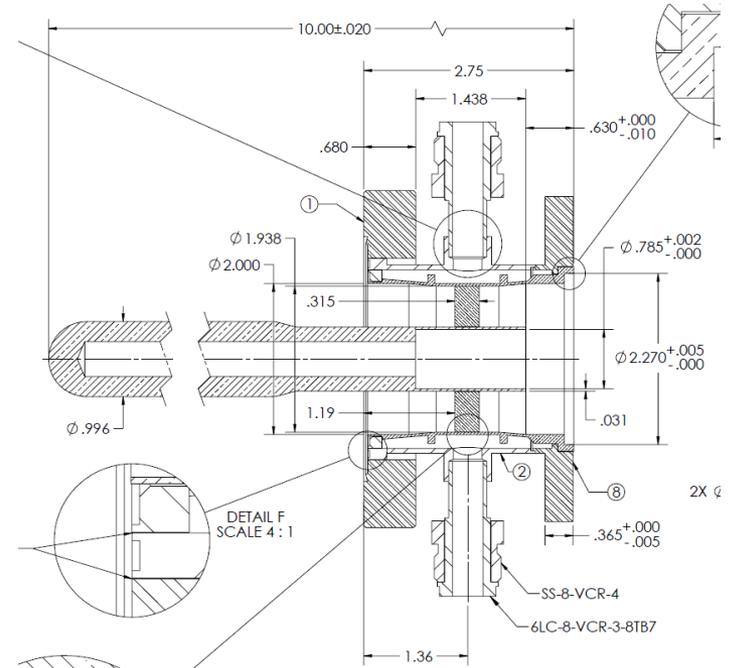
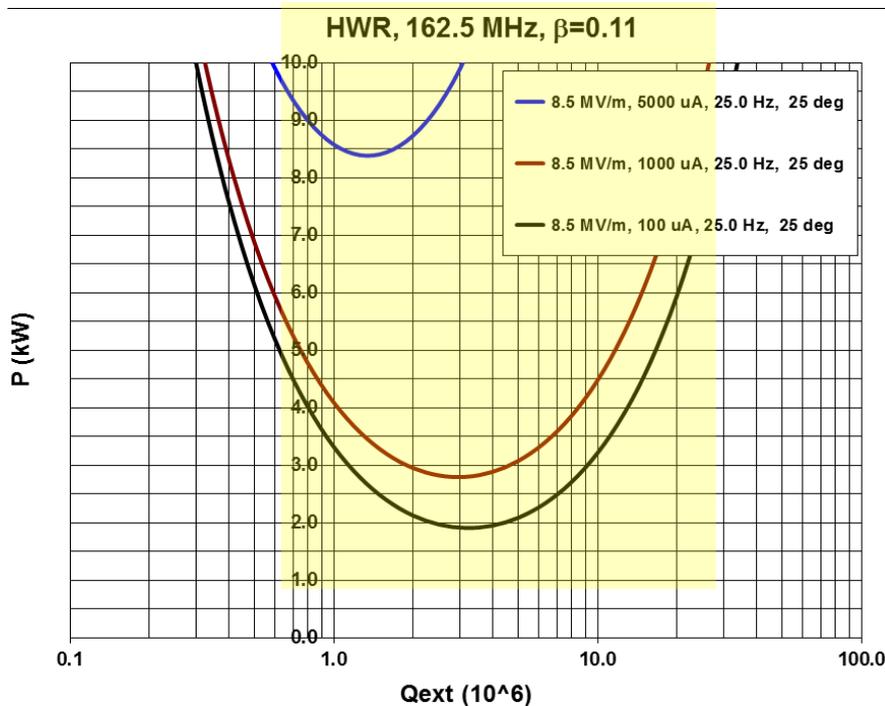
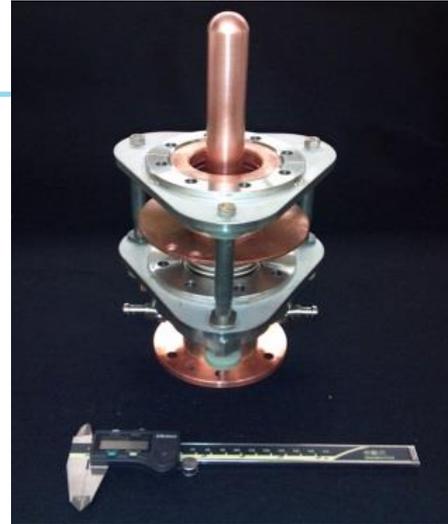
Current leads (FNAL)

SC solenoid in helium
vessel. C-flange was
changed to conflat



RF Couplers

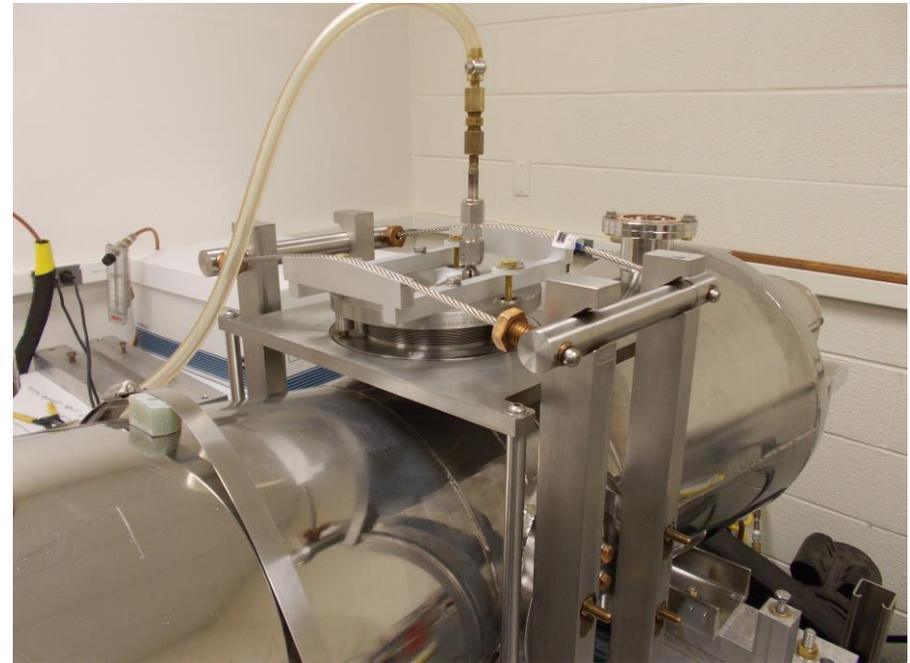
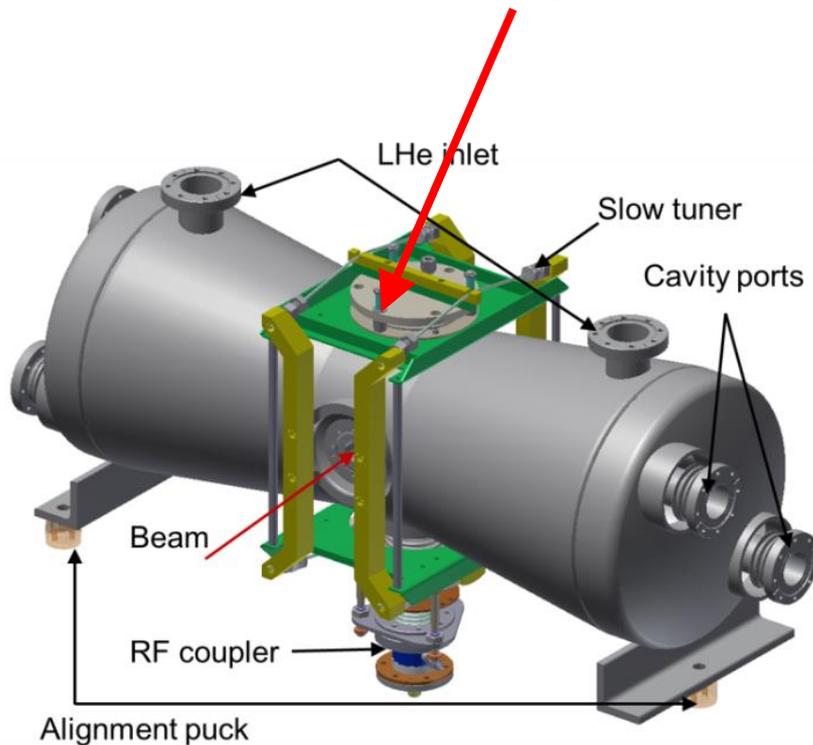
- Prototype was tested up to 5 kW RF power
- Production units
 - all components on hands
 - the cold windows with the antennas of right length are being built at MPF
- Copper plating of all bellows is complete



Slow Tuners

- All parts are on hands
- Slow tuner successfully operated for several thousands cycles at room temperature without posts and bushing

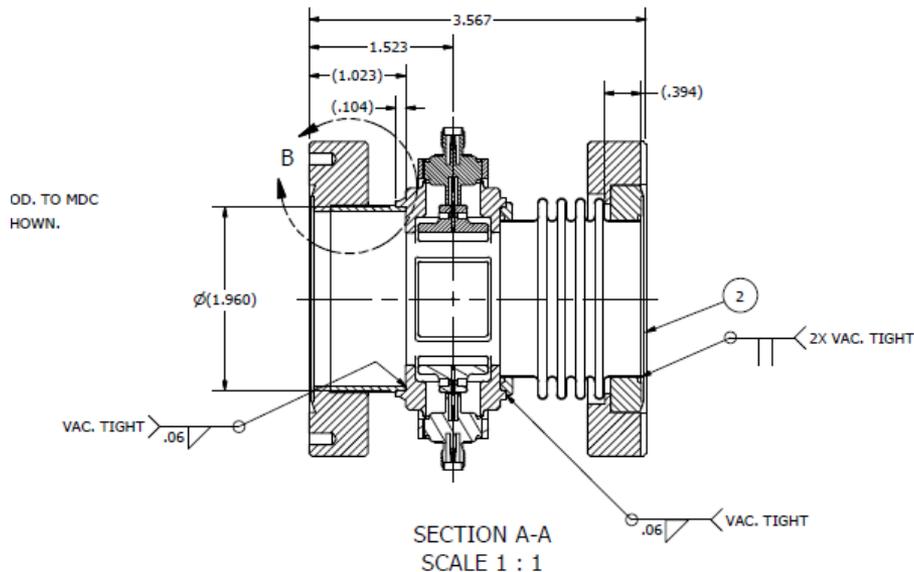
Guide posts & bushing were removed



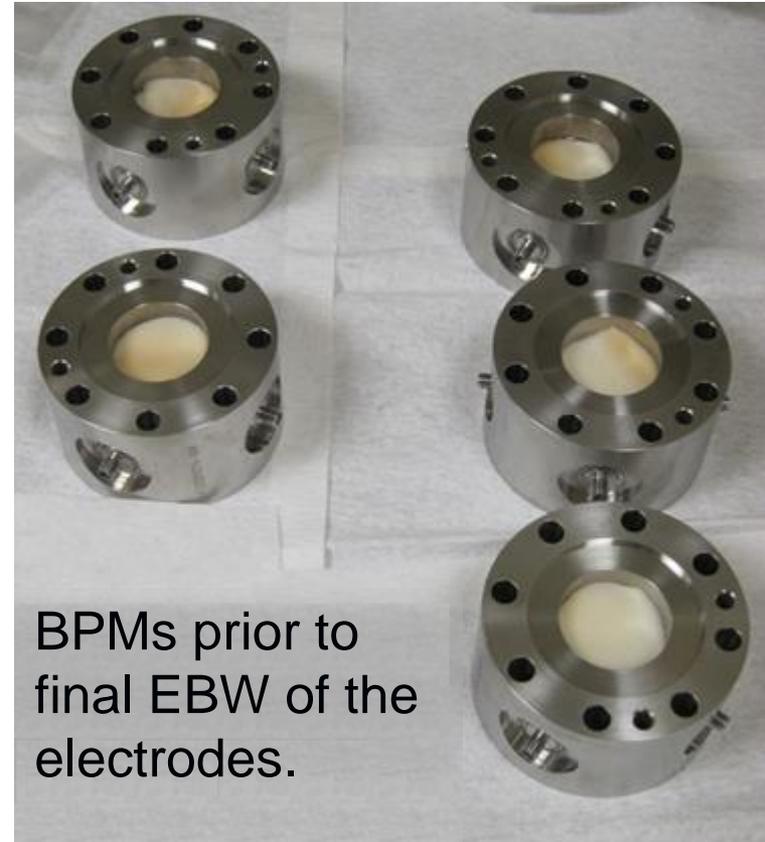
BPMs

- HWR cryomodule BPMs (10 units)
 - Prototype was tested and transferred to FNAL
 - Welding of electrodes is complete
 - Bellows/flanges are being attached.

ANL Style BPM Assembly



FNAL SSR1 BPMs

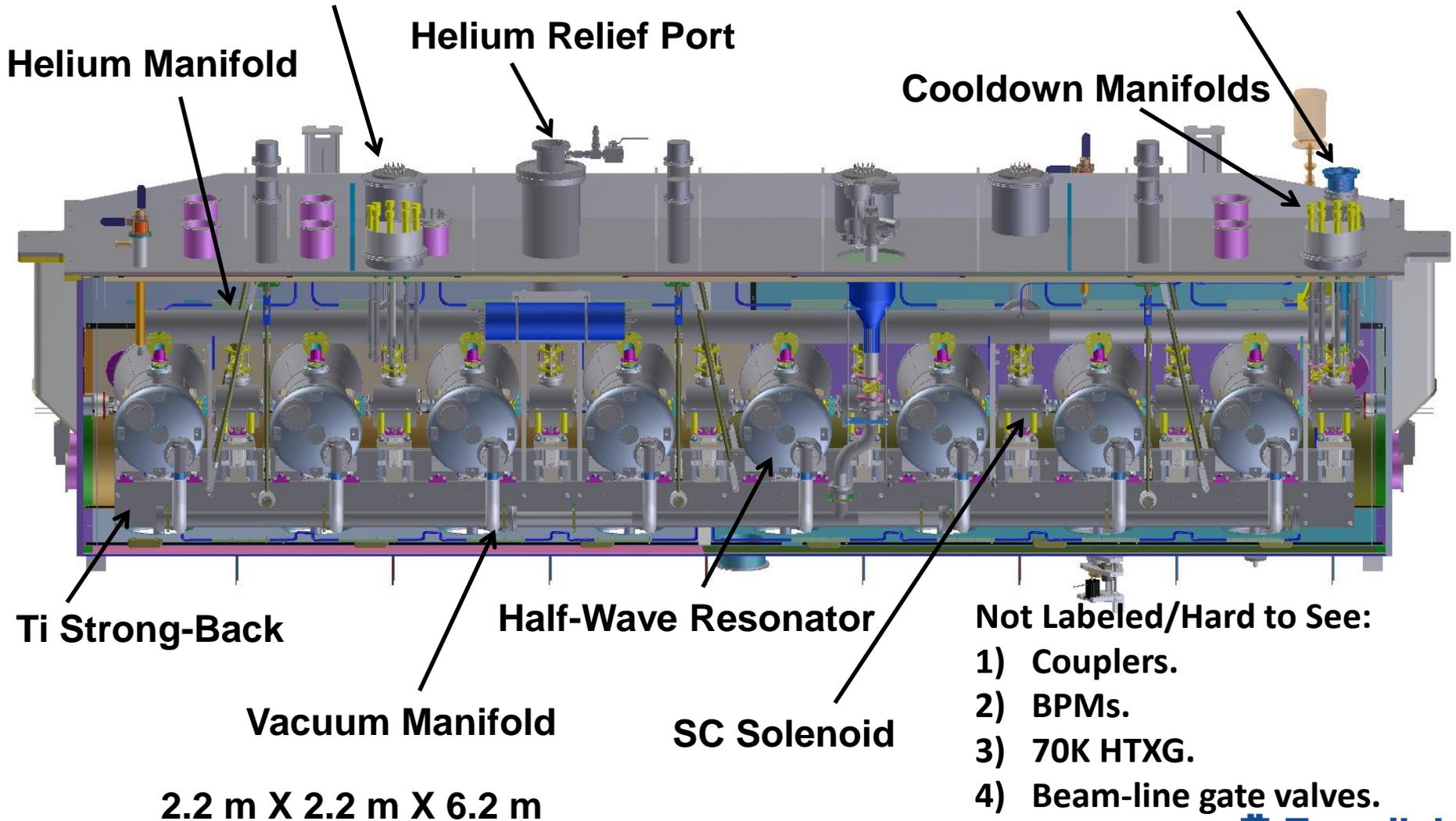


BPMs prior to final EBW of the electrodes.

HWR Cryomodule

Conduction Cooled Leads (FNAL)

Sub-Atmospheric HTXG Assembly

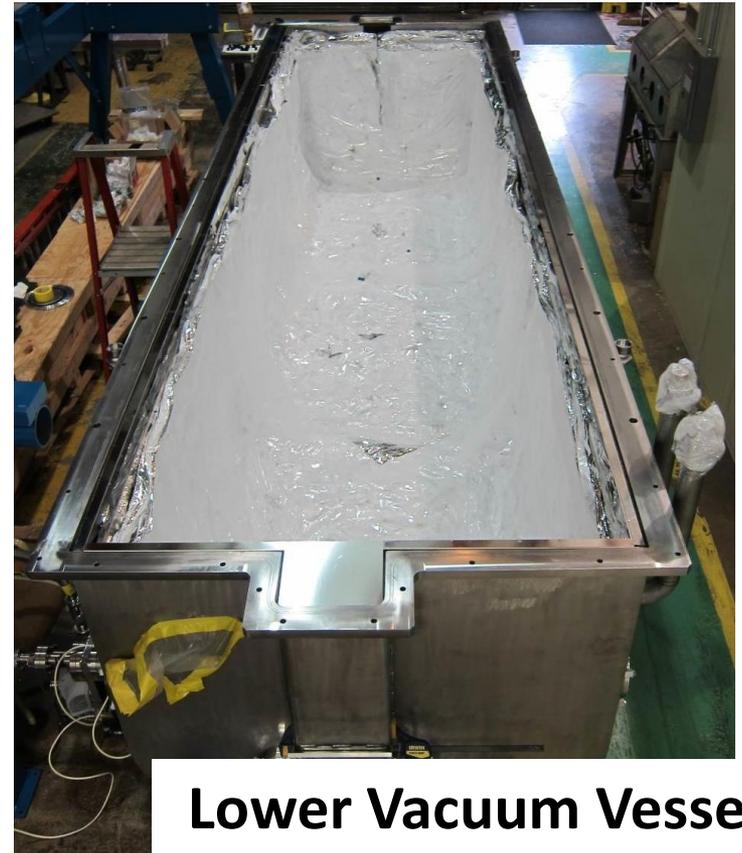


Vacuum Vessel

- All penetrations are leak tight
- Next task is engineering cool down to 77K in Q2FY16 with the goal of:
 - Heat load measurements
 - Alignment of the strongback



Full Assembly



Lower Vacuum Vessel

Other Sub-Systems

- Nearly all parts of the cryomodule on hands
- Remaining procurement & fabrication (total for ~\$350k)
 - Gate valves
 - Clean and “dirty” assembly hardware
 - MLI, thermal intercepting & cooling
 - Remaining instrumentation
 - Remaining vacuum components
 - RF Cables
 - BPM flanges
 - Up-to-air system
 - Transportation fixturing

Sub-Atmospheric Heat Exchanger Leak Check



Assembly for Engineering Cool Down



Plans for FY17 and FY18

	Deliverables, FY17	
1	Develop fixturing for the transportation of the assembled cryomodule	Q1FY17
2	Complete clean assembly of the cavity-solenoid string	Q2FY17
3	Complete design documentation as built	Q3FY17
4	Complete assembly of the cryomodule, vacuum testing	Q4FY17

	Deliverables, FY18	
1	Relocate the assembled cryomodule in bldg. 203 for cryogenic testing	Q1FY18
2	Vacuum and cryogenics testing of the cryomodule	Q2FY18
3	Delivery and installation in the PXIE tunnel at FNAL	Q3FY18

Additional ANL Contribution to PXIE R&D

- Assist FNAL in overall integration of SRF-related systems
 - Integration of HWR cryomodule (RF, cryogenics, vacuum, alignment, slow tuners,...)
 - Development of vacuum interlock system
 - Development of cryogenic interlock system
 - Troubleshooting
 - Cool down
 - RF commissioning
 - Beam commissioning
- All these tasks can be realized with 1 FTE funding over 3 years
 - 30% in FY16
 - 30% in FY17
 - 40% in FY18

Conclusions

- All FY15 milestones except one were successfully completed
- We are on track with all FY16 milestones